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Using Nudges to Promote Healthy Food Choices in the School Dining Room: A Systematic Review of Previous Investigations

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Abstract

There is a growing interest in low-cost interventions that modify obesogenic environments to encourage positive behaviour change. We have conducted a systematic review of the studies that used behavioural nudges to promote a healthy school cafeteria environment. A focused literature search was conducted using five databases; out of 381 papers, 25 were included in the present review and assessed using the Quality Assessment Tool for Quantitative Studies.

Most studies used relatively small, convenience samples and data collection methods that could not be described as robust, necessitating cautious interpretation of their results. A range of behavioural nudges were employed. Seventeen studies reported positive effects on children's selection and 11 studies reported improvements in their consumption of target

foods, effected by changing the order of serving; increasing the convenience, attractiveness, and normativeness of selecting healthy options; increasing the variety available; and attractive target food labelling.

Overall, this review identified the requirement for well-designed and well-controlled investigations into the effects of changing the choice architecture in school cafeterias, assessing short-, medium-, and long-term changes in individual children's consumption, utilising validated measures, and conducted across a variety of settings, including dining rooms of schools outside the US.

Key Words: Choice architecture; nudge; obesity; school dining rooms; school canteens; school cafeterias; healthy eating interventions; behaviour change; children.

BACKGROUND

Investigations into children's diets indicate that they have a preference for foods high in fat [1,2], sugar [3,4] and salt [5,6]. Children regularly indulge in these "junk food" items [7] but fail to consume fruit and vegetables [8-10], in spite of being aware of the associated health benefits of a diet rich in those foods [11]. Overeating and poor dietary choices significantly contribute to the high prevalence of overweight and obesity in children in the developed world. With research suggesting that dietary habits and weight in childhood and adolescence are significant predictors of dietary habits [12] and weight related issues [13] in later life, interventions promoting healthy eating during childhood could have the potential to protect against future weight related health issues [14].

A convenient setting for healthy eating interventions in childhood is the school dining room at lunchtime. Many schools allow pupils the option of bringing their own lunch to school from home or choosing hot or cold meals provided in the school canteen. It is these

52 school cafeteria meals (school dinners) that offer the greatest potential for systematic
53 intervention implementation as most aspects of the meal experience, from choice to
54 environment and serving size, can be easily controlled, monitored, and measured. Many
55 multicomponent interventions have been designed to target school lunch nutrition, but they
56 can be time costly and require considerable resources and expertise to implement effectively
57 [15, 16], though the costings of such interventions are not typically published. As a result,
58 funding bodies may be more likely to opt for cheaper, less effective interventions.
59 Could interventions that change the choice architecture [17] of the lunchroom to
60 promote healthy food choices yield significant and lasting changes in children's
61 consumption, without the time and resource costs associated with more intensive
62 interventions? Choice architecture refers to the ways that the environment presents certain
63 behavioural options to an individual, and can be altered in order to increase the salience and
64 convenience of target behavioural choices. Modifications to the environment to promote
65 target behaviours are usually referred to as behavioural nudges. Some healthy eating
66 programmes have incorporated such modifications, such as providing each child with
67 colourful "Fruit" and "Vegetable" containers to encourage them to take fruit and vegetables
68 to school [18].
69 Whilst intensive, multicomponent programmes may utilise nudges to complement
70 their intervention, a new generation of relatively simple, low-cost interventions entirely based
71 around behavioural nudges have surfaced in the literature, and report promising results for
72 behaviour change. Recent systematic reviews have examined the effects of nudges on eating
73 behaviour in adults [19, 20]; the role of nudging as a part of a multi-component review of
74 childhood healthy eating influencers [21]; and whether nudging can help to increase children's
75 vegetable consumption [22]. The present paper adds to this literature by reporting the first
76 systematic review of the effects of behavioural nudge interventions that have modified choice

77 architecture of school canteens at lunchtime, to influence children's food selection and
78 consumption.
79
80
81 **METHOD**
82 **1.** ***Search Strategy***
83 To identify interventions using only behavioural nudges to promote healthy food item
84 choice or consumption in the school cafeteria, a literature search was conducted. Five
85 databases for peer reviewed scientific literature and unpublished grey literature were used to
86 retrieve articles published since 2000 (prior to which the cafeteria environment may have
87 changed too significantly to draw comparison); these included Google Scholar, Science
88 Direct, PubMed, PrePubMed, and Web of Science. The search terms used comprised of
89 words and phrases associated with the phenomenon of interest: setting ("school canteen",
90 "school cafeteria", "school eating", and "school dining"); intervention type ("nudges",
91 "choice architecture", "environmental interventions", and "environmental variables"); and
92 target behaviour ("healthy eating", "fruit/vegetable consumption" and "healthy choices").
93 Time was taken to ensure that different combinations of key terms were searched on each
94 database. Following this, whenever we identified multiple papers as coming from the same
95 authors, we also conducted a search of their lab website. Finally, for all identified relevant
96 papers, we investigated which studies they cited, and who cited their work in turn
97 ("snowballing"). This mixed search methodology was successful in identifying several
98 unpublished theses, reports, and papers that used vague key words; it minimised the confound
99 effects that may be caused by publication bias and "file drawer problem" [23].
100
101 **2.** ***Selection Process***

This search yielded a total of 3681 potentially relevant studies, which were screened according to the postulated inclusion criteria – (1) simple nudge-only interventions, (2) focused on increasing healthy food and drink choice, (3) conducted in school cafeterias at lunchtime (e.g. no breakfast clubs or snacktime interventions), (4) reporting at least one outcome measure for food selection or consumption (e.g. studies where participant's opinions about healthy food were the sole outcome measure were not included), (5) some form of experimental control was utilised (given the pilot nature of most studies, baseline vs. follow up in a single sample was acceptable), and (6) had been published since 2000 (inclusive, to ensure comparable environments); however, no relevant studies prior to 2012 were identified. Studies were excluded if (1) changes were made to canteen provision to reduce choice (e.g. unhealthy options were no longer offered in the canteen), (2) the participants were not a typical school population sample, or (3) the nudge was a part of a multicomponent intervention.

3. Methodological Quality

All studies identified as appropriate for inclusion were assessed for quality using the Quality Assessment Tool for Quantitative Studies (QATQS [24]). This practice is recommended as an appropriate tool for use in the systematic review of intervention effectiveness [25]. Using this tool, studies were scrutinised and rated on a three-grade scale (weak, moderate, or strong) on six methodological and reporting dimensions: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and drop-outs. However, it was agreed that this last category was not applicable, because in most of the reviewed studies individual consent and individualised data were not recorded.

A global rating was then calculated according to the QATQS guidelines. Those studies that had achieved at least a strong or moderate rating on the five dimensions merited a

strong global rating; a moderate rating was given to those studies that obtained a weak rating on one of the dimensions; and a weak rating was given if two or more dimensions were rated as weak. To ensure inter-rater reliability, two researchers (the first and the last authors of this paper) independently rated each study. Disagreements were discussed until a final verdict on study quality was reached.

4. Data Extraction and Synthesis

Data and QATQS results of the final sample of studies meeting the inclusion criteria were tabulated. Table 1 details QATQS scores for each study, in each category and overall. Table 2 summarises key features of studies examining influences on milk, fruit, and vegetable consumption. Table 3 presents these details for studies examining global nutrient change.

LITERATURE REVIEW

1. Results Search Strategy

Of the 381 studies identified by the search strategy, 311 were eliminated based on titles and abstracts and the full text of 70 studies were retrieved and reviewed. Following this, 25 studies were included in the final review. Most excluded articles were removed on the basis of using nudges as one component of a complex multicomponent intervention. Such studies were deemed outside of the scope of the present review because the effectiveness of the nudge components alone could not be ascertained. The paper selection procedure is summarised in Figure 1.

Insert Figure 1 about here

152

153 ***2. Methodological Quality of Included Studies***

154 Prior to discussions, independent raters reached agreement levels of 67% - 100% in
155 each of the six QATQS categories. Following discussion, a final verdict was agreed for each
156 rating; disagreements were small and related to different reading of study questions or the
157 assessment tools. No third party was required to reach an agreement.

158 [Insert Table 1 about here]

159 Table 1. QATQS scoring results for studies included in this review.

160 As can be seen from Table 1, 4 studies yielded a strong global rating [26, 37, 45, 49]; the
161 global rating of 12 studies were moderate [27-29, 32, 33, 38-41, 46-48]; while the remaining 9 studies were
162 rated as weak [30, 31, 34-36, 42-44, 50].

163 Sample ("selection bias") was rated as weak in 5 studies [34, 36, 42, 44, 50]; moderate in 15
164 studies [26, 29-33, 37-39, 41, 43, 45-48, 49]; and strong in 4 studies [27, 28, 35, 40]. Issues negatively affecting ratings were
165 generally associated with opportunity sampling (where local schools were used) or volunteer
166 sampling (e.g. a small percentage of engaged parents consented to the intervention) whereby
167 participants may not have been fully representative of the general population.

168 Twenty-four study designs were rated as moderate, with only one study rated as weak
169 [43] (the design of the study was unclear). Due to the nature of the research, no studies were
170 randomised controlled trials, as participants were assigned to intervention or control groups
171 by cohort rather than by individual case. As a result, studies were either described as cohort
172 [26, 29, 31-34, 37, 39-42, 44, 46, 47, 49] or cohort analytic [27, 28, 30, 35, 36, 38, 40, 45, 48, 50]. Of the 10 studies including a control group,
173 7 described the group allocation procedure as randomised [27, 28, 30, 35, 36, 38, 45], however, only one
174 paper described a randomisation procedure [28].

175 Of those papers described as cohort analytic (includes a control group and pre- and
176 post-test measures for comparison), no important differences were identified between groups

177 at baseline on key potential confounders in five papers [27, 28, 36, 38, 45], with four papers reporting
178 notable differences between groups [30, 35, 48, 50], the one remaining paper did not report sufficient
179 information to assess confounding factors between groups [38]. Regarding blinding, the
180 outcome assessors were aware of the participants' exposure status in every study except one
181 [42], whilst only one paper [49] reported whether or not participants were made aware (or
182 blinded from) the purpose of the study.
183 Data collection methods were generally weak [27-36, 38-42, 44, 46, 47, 49] with most studies utilising
184 visual observation methods without establishing their validity and reliability. One study [28]
185 utilised visual observation methods and provided references to a previously validated
186 protocol [51], however, a low rating was awarded due to coding errors resulting in a loss of a
187 large quantity of the data. Another study [37] utilised a reliable digital photography data
188 collection method [52], however, validity for this method was not reported, and so a moderate
189 rating was awarded for data collection on this paper. One other paper [26] achieved a moderate
190 rating, whilst five studies yielded strong ratings [43, 45, 48-50].
191
192 ***3. Study Findings***
193
194 The following summary of the findings of the studies included in the present review is
195 sub-categorised by target outcome behaviour.
196
197 ***Healthy Milk Choice***
198 Two of the included studies focussed on increasing white milk selection (see Table 2).
199 Goto et al. [27] conducted their study using two intervention and one control school. The first
200 intervention made selection of chocolate milk more "effortful" than the healthier white milk
201 option (students had to ask for chocolate milk rather than being able to select it from stands

by the cafeteria tills), whilst the second intervention increased the "availability and prominence" of white milk (by maintaining a three-to-one ratio of white milk to chocolate milk on the milk stands). In this study, the sole significant change was an increase in white milk selection for those participants in the "increased effort" condition.

Samek [35] conducted his study using 90 grade 6 classes. It employed two intervention groups and one control group. The first intervention encouraged children to take healthier white milk instead of chocolate milk by giving children a "gift" (a sticker) to thank them "in advance" for selecting white milk. The second intervention involved asking children to set themselves the "goal" of choosing white milk by filling in "goal setting cards" before entering the dining hall. In the control school, children were read an educational message about sugar in white and flavoured milk. Children were not obliged to take white milk in any condition, and continued with their normal lunchtime routine. Results indicated that in the control condition, selection of white milk increased significantly from 11% at baseline to 47.8% on the day they received the educational message. White milk selection increased significantly compared to baseline selection and the control group in the "gift" and "goal" intervention groups (from 11% to 65.5% and 54.8%, respectively). It is not possible to assume that these effects would remain stable over time and have a lasting impact on children's milk choice due to a lack of follow-up observation. One key limitation of this research is the significant increase in milk consumption in the control group, indicating that there was a substantial influence of simply drawing children's attention to milk choices, but this impact was not addressed nor controlled for.

Fruit and/or Vegetable Consumption

Fifteen studies aimed to employ nudges to increase fruit and/or vegetable selection and/or consumption (see Table 2). Elsbernd et al. [26] examined the influence of serving a portion of bell peppers in the dinner line on total vegetable consumption. Children were

offered a portion of bell peppers "to eat right now" before they were served the rest of their meal. Although the mean weight of peppers consumed by students who took a serving of peppers did not significantly increase, a significant increase in total number of children eating peppers was identified, resulting in a significant increase in total vegetable consumption, compared to baseline.

Green et al. [28] tested the effectiveness of the Smarter Lunchroom programme. This paper reported that targeting fruit by several nudges, including increasing the choice and appearance of the servings, convenience of their selection, labelling, and information provision, led to significant increases in the selection and consumption of this target food, accompanied by some increases in the selection and consumption of vegetables and milk. These effects were recorded in the four intervention schools but not in the three control schools.

Hakim and Meissen [29] attempted to increase fruit and vegetable consumption for those children served free or discounted school meals by introducing more active choice into the forced-choice paradigm. This intervention involved increasing the number of fruit or vegetables available to participants on alternating days (e.g. on a "vegetable" day, students had a choice of five varieties of vegetable but were served the standard fruit available on that day). Results indicated that consumption of both fruit and vegetables increased significantly compared to baseline.

Hanks et al. [30] aimed to increase selection of vegetables from the salad bar using visual nudges. A control school and three treatment conditions were utilised. No changes were made in the cafeteria of the control schools. In the "banner" intervention group, a brightly coloured banner depicting cartoon vegetable characters was placed around the salad bar. In the "television" group, screens playing health education messages delivered by vegetable characters were placed in the cafeteria. In the "banner and television" group, both

media prompts were utilised. Results indicated a significant increase in the number of salad and vegetable servings taken in the "banner and television" condition, but not in either condition where only one type of media was utilised, compared to baseline.

Keller [31] assessed the effectiveness of three nudge techniques, utilised independently, on 6th grade students' selection and consumption of fruit. Following a three-day baseline data collection period, on intervention day one, stickers were placed on whole pieces of the fruit available to buy at lunchtime (apple) by way of "branding"; on day two, the fruit available (banana) was digitally advertised on television screens in front of the dinner queue; on day three, two types of fruit were offered (grapes and kiwi), increasing the variety of fruit available. The branding intervention was found to have no impact on apple selection, and indeed was associated with a decrease in consumption, whilst digital advertisement intervention prompted an increase in banana selection, though banana consumption was significantly reduced. The most successful nudge was increasing the variety of fruit available, which was associated with a significant increase in fruit selection, though consumption remained constant.

Miller et al. [32] increased portion sizes of fruit and vegetables served at lunchtime to investigate the subsequent effects on overall consumption. Following one day of baseline data collection, the portion sizes of baby carrots, oranges, and apple sauce were increased, though no other changes were made to the lunchtime routine. Results indicated a significant increase in mean consumption for apple sauce and oranges, but no significant increases in baby carrot consumption. Researchers noted that this may be due to the low levels of vegetable selection, and difficulty eating a large portion of raw baby carrot compared with the ease of eating apple sauce or pre-sliced orange wedges.

Reicks et al. [34] studied the effect of visual prompts on the amount of green beans or carrots consumed. Data were collected on two days (control and intervention), spaced three

277 months apart. No changes were made to the lunchtime routine on the control day, however,
278 on the intervention day photographs of available vegetables were placed in the compartments
279 of dinner trays designated for vegetable servings, so that children identified these areas as
280 where vegetables "should go". There was an increase in percentage of children who selected
281 the target vegetables, but no overall increase in the average consumption of either vegetable
282 (indeed, carrot consumption declined between control and intervention collection dates).
283 Redden et al. [33] investigated the impact of serving a portion of vegetables in the
284 dinner line on total vegetable consumption. In study 1, children were able to select a portion
285 of baby carrots, a relatively well-liked vegetable, to eat in the dinner line. No other changes
286 to provision or serving were made. This study was conducted on two days, spaced three
287 months apart. Results showed that participants consumed significantly more carrots on the
288 day when this option was available. Their second study was longitudinal, conducted over five
289 days (one control day, three intervention days, one post-test control day) spaced two or three
290 weeks apart. As before, children were able to select a vegetable portion (a relatively disliked
291 vegetable, broccoli) to consume in the dinner line. Results indicated that children consumed
292 significantly more broccoli on intervention days compared to control days. A strength of this
293 study manifests in the generalisability of results between relatively liked and relatively
294 disliked vegetables.
295 Schwartz [36] used verbal prompts to encourage fruit and fruit juice consumption. No
296 changes were made at lunchtime in the control group; however, the intervention were given
297 one simple verbal prompt by cafeteria staff to encourage selection: "Would you like fruit or
298 juice?". Results indicated that, on the first day of the intervention, children in the intervention
299 school selected more fruit following verbal nudges, and on the second day, children in the
300 intervention school were more likely to take fruit or juice, although the difference between
301 groups had decreased for fruit selection. Although they were not more likely to consume their

302 fruit than the control school (approximately 80% of students in each group who selected fruit
303 also ate it), increased selection still led to greater levels of consumption. Unfortunately, data
304 collection relied on visual counts from parents, rather than trained observers, with no means
305 of establishing validity or reliability of this method.

306 Swanson [37] investigated the impact of ease of consumption on selection and
307 consumption of apples and oranges. Oranges and apples were either served as half of a piece
308 of fruit sliced into three wedges (day 1, intervention), or as a whole piece of fruit (day 2,
309 follow-up control) during the lunch period. Selection and consumption of sliced oranges were
310 greater compared with when whole oranges were offered, though this effect was not observed
311 for sliced apples, for which selection and consumption were comparable across intervention
312 and control days.

313 Wansink et al. [38] also assessed the influence of serving sliced fruit on the selection
314 and consumption of apples, in New York middle schools. Apples were either served whole
315 (control schools) or pre-sliced using a commercial fruit slicer (intervention schools). Apple
316 sales increased by 71% in the intervention school compared with the control school;
317 however, there was no change in percentage of apples consumed. A strength of this research
318 was a prior identification of barriers to fruit consumption. Using interview techniques,
319 researchers discovered that whole pieces of fruit could be difficult to eat for young children,
320 especially those with teeth missing or braces, and that older girls found eating whole fruit to
321 be messy and unattractive in front of peers.

322 Wansink et al. [39] evaluated the influence of branding on apple consumption in seven
323 school. This study took place over five days where children were given the option to choose
324 either an apple and/or a cookie. On the control days (days 1 and 5), neither the apple nor the
325 cookie were branded. On intervention days (days 2 - 4), children were either offered an apple
326 branded with a sticker of a well-known cartoon character (Elmo), and/or an unbranded

cookie; a branded cookie (as before) and/or an unbranded apple; or an apple branded with a sticker of an unknown character and an unbranded cookie. Selection of Elmo-branded apples significantly increased compared to control conditions, though no effect was found for branding on cookie selection, nor were any effects observed for apple selection when an unknown cartoon character sticker was used.

Wansink et al. [40] investigated the use of attractively named vegetables to promote and maintain vegetable consumption. In their first study, children ate significantly more carrots when they were labelled "X-ray vision carrots" than when they were labelled "Food of the day" or were unlabelled. In Study 2, hot vegetables were given attractive names in the school cafeteria (e.g. "Power Punch Broccoli"), and data automatically collected by cash registers indicated that students were much more likely to select a hot vegetable if they had an attractive label than students in the no-label control group.

Zellner et al. [41] investigated the influence of the order of serving fruit on the consumption of vegetables at school mealtime. On two separate days, more than two months apart, children were either served their portion of fruit with their meal (control condition), or after their meal as a separate dessert course. Results indicated that participants consumed significantly more target vegetable (kale) when fruit was served as a separate course, though "liking" ratings remained constant. This indicates that the mere presence of a more liked competing food item may reduce consumption of a less liked food item, even if the consumption of one does not require the displacement of another. Curiously, the authors did not report children's consumption of fruit in either condition.

Zhuzhina [42] implemented a "Smarter Lunchroom Makeover". Following baseline data collection, the school lunch halls were modified to incorporate several behavioural nudges; signage featuring new names for fruit and vegetables along with personified images were displayed, decorative plastic bowls containing sliced fruit were placed on the salad bar,

and wicker baskets containing whole pieces of fruit were also displayed. Results indicated that the intervention had been successful in increasing fruit and vegetable selection in only one of the intervention schools, compared to baseline, though the likelihood of students consuming a whole serving of fruit or vegetable, once they had selected it, increased in both schools during the intervention.

[Insert Table 2 about here]

Table 2: A synopsis of the included studies that focus on healthy milk choice or fruit and/or vegetable consumption.

Global Nutritional Improvement

Eight studies assessed global nutritional improvement as an outcome measure, with interventions that aimed to target general healthful food selection and consumption (e.g. including whole grains and a reduction in less wholesome alternatives), as shown in Table 3. Ensaff et al. [43] investigated the impact of changes to the choice architecture on students' selection of plant-based foods. Small changes were implemented in the cafeteria to make target foods more attractive, including (a) selling vegetarian daily specials in disposable plastic pots; (b) placing stickers on sandwiches containing salad; (c) displaying promotional posters for sandwiches containing salad; (d) placing stickers on fruit pots; (e) creating attractive displays for whole fruit; and (f) displaying window stickers promoting whole fruit. Results indicated that these nudge strategies were associated with an increase of target food selection in the intervention school, while no changes were identified in the control school.

Graham [44] assessed the influence of the presence of a "traffic light" system of nutritional coding (e.g. red-coded meals contain more fat) on pre-ordered entrée selection. A number of different pre-ordering systems were set up during a nine-week baseline data

collection period, which was immediately followed by a short lesson on the meaning of the traffic light nutritional coding system. The remaining 23 days comprised the intervention data collection, where children pre-ordered their meals as before, but entrées were now coded with the traffic light system. Results showed minimal change in entrée selection associated with nutritional labelling, though selection of "green" entrées were more likely if there was more variety in "green" entrée choice.

Hanks et al. [45] also assessed the influence of pre-ordering lunch, although this investigation focussed on healthy entrée selection alone. Fourteen classes were randomly assigned to one of three conditions: continuous pre-ordering, pre-ordering with a week break, or discontinuing pre-ordering during the last week. Results indicated that those children who pre-ordered food were more likely to choose a healthy entrée (29.4%, compared with 15.3% when no pre-ordering was available). Unfortunately, although consumption data were collected, no reference was made to the data collection protocol, nor were these results reported.

Hanks et al. [46] assessed the impact of their "smarter lunchroom makeover" on selection of fruit, vegetables, healthy sandwiches, and starchy sides. This involved several nudge strategies that increased the convenience, attractiveness, and normativeness of target foods, and led to a significant increase in the selection and consumption of fruit and vegetables (no changes were noted in the selection or consumption of other target food items).

The last experiment reported by Hanks et al. [47] investigated the impact of a dedicated "convenience line" on selection and consumption of healthy foods and white milk. This involved changing the options in one of the convenience lines in the dining room so that only healthy foods and sandwiches were available. Results indicated that following this change, students selected significantly more healthy food items (although there was no difference in

healthy food item consumption) and consumed significantly fewer unhealthy food items. Total milk sales also increased, albeit as the result of a significant increase in flavoured (comparably less healthy) milk selection.

Miller et al. [48] investigated the influence of pre-ordering school lunches on selection of food items contributing to a nutritionally balanced meal, including all five lunch components (grain, entrée, fruit, vegetable, and dairy). Children were assigned to either a control group or one of two treatment groups. In both treatment groups, children pre-ordered their meal using a computer app which displayed all food items available in the appropriate lunch component categories. Children in the first intervention group were made aware of the five categories but selected and submitted their choices without further nudges. In the second intervention group, children who did not select a food item for each category received the message, "This does not look like a balanced meal," with the missing categories highlighted. Children then had the option to select more food items or continue with their order. Results showed that children in both treatment groups selected significantly more fruit, vegetables, and low fat milk than children in the control group, whilst children in the second intervention group selected significantly more fruit, vegetables and low fat milk than those in the first intervention group.

Siegel et al. [49] investigated the use of "emoticon stickers" to promote white milk, fruits, vegetables, and healthy entrées. Following a two month baseline data collection period, stickers with a green smiley face were placed on healthful food options, and cafeteria staff explained at the beginning of the intervention, and intermittently throughout, that this meant the food item was a healthy choice. This intervention lasted for two months, and no other changes were made to the cafeteria or the food service procedure during this time. Results showed a significant increase in white milk selection, displacing chocolate milk

selection so that overall milk selection remained constant. Vegetable selection also increased, though no significant differences were observed for fruit or healthy entrée selection.

Wansink et al. [50] investigated the use of "nutritional report cards". Food selection information collected automatically by cash registers was sent via email to parents in the form of a nutritional report card. It was hypothesised that children would make healthier choices at lunchtime if they knew that their parents were aware of what they had chosen. However, no significant difference was recorded on any of the target food items, except for cookie selection, which significantly decreased from 14.3% to 6.5%.

[Insert Table 3 about here]

Table 3: A synopsis of the included studies that focus on global nutritional improvement.

DISCUSSION

This systematic review identified 25 papers reporting the results of simple behavioural nudges intended to promote healthy eating in the school cafeterias. The results of 17 studies indicated an increase in selection of a target healthy food [27, 28, 30, 31, 34-38, 40, 42, 43, 45-49] and 11 studies reported a significant change in target food consumption [26, 28, 29, 31-33, 37, 40-42, 46]. One study reported no significant change in selection or consumption [50]. Overall, it has been reported that selection of target healthy food items can be increased by making choosing unhealthy food items more effortful, displaying attractive posters and videos promoting target food selection in the lunch room, prompting children in the dinner line to select healthier options, and pre-ordering meals before joining the dinner queue. Consumption of target healthy food items has been increased through changing the order of serving for vegetables, increasing the

convenience, attractiveness, and normativeness of selecting healthy options with "smarter" lunchrooms, increasing the variety of fruits and vegetables available, and renaming target food items with attractive, exciting names.

We have been surprised to find that the effectiveness of simple nudge-based interventions has not yet been explored outside of the US school environments. Only one of the reviewed studies was conducted in the UK [27]. Within the US cohort, 9 out of the 25 studies had been conducted by the same research team or their associates [28, 30, 38-40, 45-47, 50]. The possible benefits of cafeteria-based dietary nudge interventions need to be explored in a wider range of schools in Europe, where school-provided lunches are common. Although the nutrition standards of these meals have been improving in most developed countries, children's diets consistently contain fewer fruit and vegetables than is recommended [8-10].

We also found that, in around a third of included papers, the authors did not collect consumption data. Instead, effectiveness of the nudge interventions was evaluated using food item selection data. Whilst collecting purchase data at the point of sale may be reliable, provision and selection of food items does not necessarily equate to consumption. This resulted in poor internal validity; no conclusions could be drawn regarding the effectiveness of the assessed interventions in promoting healthy dietary habits. Further, for those studies that collected data on food item selection and consumption yet only identified a significant increase in selection of target food items, the parsimonious conclusions that may be drawn are that the intervention was successful in teaching children what observers expected of them but not in influencing actual consumption behaviour. This may have led to results that manifest social desirability bias, to which children are particularly vulnerable [53, 54]. Measuring effects in the longer term may be one way of establishing whether or not transient demand characteristics account for the changes recorded in these evaluations. Recording children's

475 eating over multiple occasions can minimise the influence of novelty and present a better
476 picture of children's typical behaviour in the school canteens.
477 Of those studies that did measure actual consumption of a target food item, most used
478 measures that demonstrated only face validity. Only two of the reviewed studies employed a
479 visual estimation protocol for nutritional data collection that had been validated for this
480 purpose [28, 51; 37, 52], and reported reliability, albeit without giving much detail. Consumption was
481 often estimated by comparing pre-consumption records, based either on visual observation or
482 on target food item sales, with subsequent plate waste records, without reporting the validity
483 or reliability of these measures. These limitations were reflected in the typically weak ratings
484 on the QATQS component describing data collection methods. A weak methodology can
485 only yield inconclusive results, and because reviewed studies did not employ sound data
486 collection methods, no firm conclusions ought to be drawn. Our own exploration of the
487 behavioural nutrition literature had revealed a scarcity of publications establishing validation
488 of instruments that can be used for measuring food consumption in a fast-paced canteen
489 setting.
490 We noted that none of the authors of the reviewed papers mentioned pre-registering
491 their research. Pre-registering anticipated results protects the integrity of the research by
492 implementing a barrier against the desire for researchers to cherry-pick data, analyses, and
493 results in order to generate the most seemingly significant data. This issue is evidenced by an
494 increasing number of journals requesting (and indeed insisting) that submitted papers must
495 provide evidence of pre-registering anticipated results prior to study commencement. This
496 good practice should be adopted in consumption research so that, where appropriate, the null
497 hypothesis can be objectively evidenced and correctly accepted.
498 In spite of their methodological weaknesses, the reviewed studies were generally
499 published in established journals. With journal impact factors ranging from 0.596 to 4.396 at

500 the time of publishing, it is evident that research into behavioural nudges to benefit
501 nutritional intake is well regarded in the scientific community. This is not surprising
502 considering the well-documented effects of obesogenic environments that children are
503 exposed to. However, significant advances in our understanding of the environmental factors
504 that can be harnessed to influence a positive change in children's eating behaviour can only
505 be made by addressing the methodological limitations highlighted in the present review. A
506 strength of the existing investigations is that they demonstrate that schools, cafeteria staff,
507 and indeed children are willing to adapt to change and are open to implementing nudge
508 interventions. This suggests that simple and inexpensive nudge interventions could have a
509 place in improving children's food choices, with the possibility of good public health
510 population impact upon an entire cohort.
511
512 **IMPLICATIONS FOR SCHOOL HEALTH**
513 None of the studies examined the changes in children's consumption on an individual
514 level. This restricted the statistical tests they could deploy, and limited the conclusions that
515 could be drawn from the data. For example, we do not know whether some of the nudges
516 may work with children who eat the least healthy diets at the outset, or are these effects
517 restricted only to those who already choose to consume fruit, vegetables, or white milk at
518 least some of the time. This information is needed before any changes to choice architecture
519 could be recommended as a tool for combating poor nutrition in schools. Further, most of the
520 reviewed studies measured immediate, short term effects of nudges on children's behaviour.
521 However, only sustained, long-term changes to eating behaviour can be expected to impact
522 on children's habits, health, and weight status.
523 This review has examined school cafeteria-based interventions that have utilised
524 behavioural nudges as the sole influencing factor for behaviour change. It was found that

many of these interventions were effective in increasing children's healthier menu choices, and in some cases their consumption of target foods, although procedural limitations that included the absence of control groups and lack of independently validated measures limited the conclusions that could be drawn from the data. Nevertheless, even these tentative results indicate a promising area for positive behaviour change, with the potential for mass implementation at low cost and significant benefits for public health. Overall, this review ultimately identified the requirement – a gap in the literature – for well- designed, and well-controlled investigations into the effects of changing the choice architecture in the school cafeterias, assessing short-, medium-, and long-term changes in individual children's consumption, utilising validated measures, and conducted across a variety of settings, including dining rooms of schools outside the US.

Declarations

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

MMO conducted the review, completed QATQS assessment, processed and analysed data, and drafted the manuscript. ME secured the funding, supervised the review process, completed QATQS assessment, and co-wrote the final manuscript. SV assisted with methodological background and editing. PJH made an editing contribution. All authors have read and approved the final manuscript.

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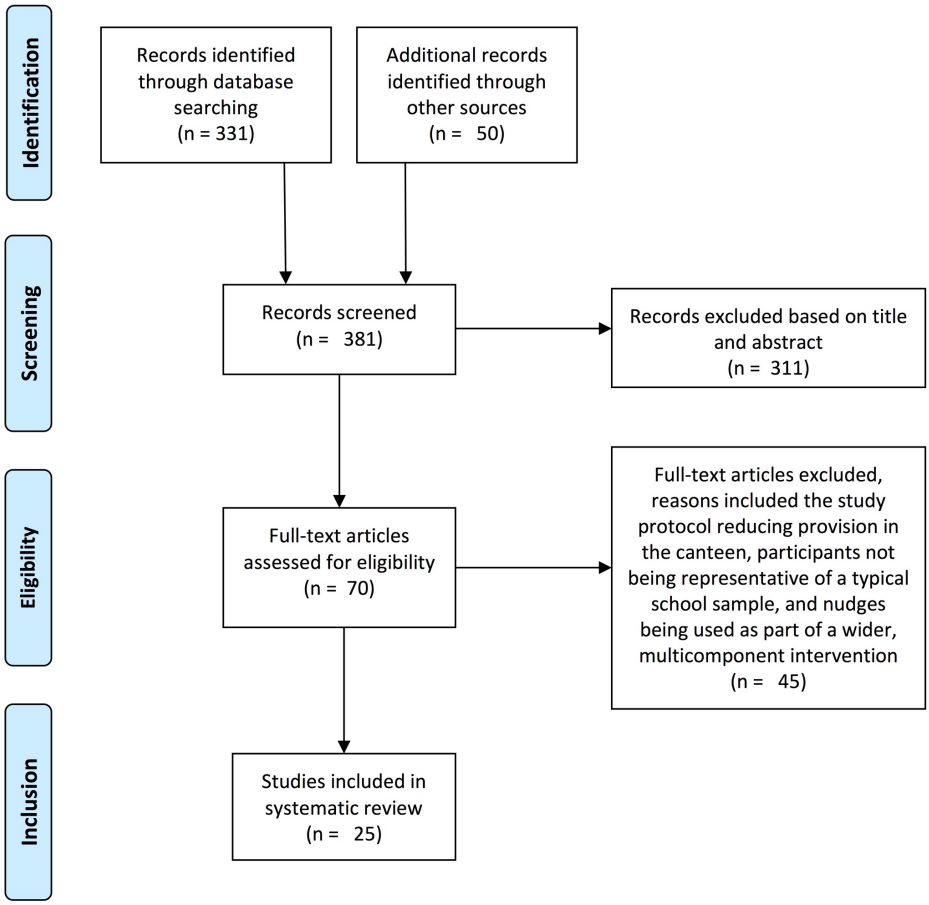
Identification
Screening
Eligibility
Inclusion
Records identified through database searching (n = 331)
Additional records identified through other sources (n = 50)
Records screened (n = 381)
Records excluded based on title and abstract (n = 311)
Full-text articles assessed for eligibility (n = 70)
Full-text articles excluded, reasons included the study protocol reducing provision in the canteen, participants not being representative of a typical school sample, and nudges being used as part of a wider, multicomponent intervention (n = 45)
Studies included in systematic review (n = 25)

706

707 Table 1. Results of the QATQS analysis for included studies.

Study/Country	Selection Bias	Study Design	Control for confounders	Blinding	Data collection	Global Rating
Elsbernd et al. (2016) [26]	**	**	***	**	**	***
Goto et al. (2013) [27]	***	**	***	**	*	**
Greene, et al. (2017) [28]	***	**	***	**	*	**
Hakim & Meissen (2013) [29]	**	**	***	**	*	**
Hanks et al. (2016) [30]	**	**	*	**	*	*
Keller (2017) [31]	**	**	***	**	*	**
Miller et al. (2015) [32]	**	**	***	**	*	**
Redden et al. (2015) [33]	**	**	**	**	*	**
Reicks et al. (2012) [34]	*	**	*	**	*	*
Samek (2016) [35]	***	**	*	**	*	*
Schwartz (2007) [36]	*	**	***	***	*	*
Swanson (2009) [37]	**	**	***	**	**	***
Wansink et al. (2013) [38]	**	**	***	**	*	**
Wansink et al. (2012) [39]	**	**	***	**	*	**
Wansink et al. (2012) [40]	***	**	***	**	*	**
Zellner et al. (2016) [41]	**	**	***	**	*	**
Zhuzhina (2016) [42]	*	**	***	**	*	*
Ensaff et al. (2015) [43]	**	*	*	**	***	*
Graham (2015) [44]	*	**	*	**	*	*
Hanks et al. (2013a) [45]	**	**	***	***	***	***
Hanks et al. (2013b) [46]	**	**	***	**	*	**
Hanks et al. (2012) [47]	**	**	***	**	*	**
Miller et al. (2016) [48]	**	**	*	**	***	**
Siegel et al. (2015) [49]	**	**	***	**	***	***
Wansink et al. (2013) [50]	*	**	*	***	***	*

708

Key

- * = Weak
- ** = Moderate
- *** = Strong

709

710

711 Table 2. A synopsis of the studies measuring milk, fruit and/or vegetable consumption.

Study/Country	Study Design	Sample Characteristics	Duration/ Measurements	Outcomes	Main Results
Elsbernd et al. (2016); Minnesota, US [26]	Cohort	1 elementary school, Kindergarten – 5th grade classes, n = 575	- 1 day control; plus 1 day follow-up control; 3 day intervention. - Visual observation, vegetable sales, and floor-waste.	- Number of students eating peppers (NP), mean weight of peppers consumed (PC), mean weight of total vegetables consumed (VC).	NP: +++ PC: [=] VC: [=]
Goto et al. (2013); Northern California, US [27]	Cohort Analytic	3 elementary schools, 2 treatment groups (T1; T2), 1 control group (C) – T1 (Ask intervention, n = 247), T2 (Increase intervention, n = 153), C (control, n = 277).	- 5 day baseline; 5 day intervention. - Milk selection recorded and milk waste weighed.	- White milk selection (MS) and percentage of milk consumption (MC).	- T1 MS: +++ Ask MC: [=] - T2 MS: [=] MC: [=]
Greene, et al. (2017); New York, US [28]	Cohort Analytic	10 Middle schools; fruit intervention (n = 4); vegetable intervention (n = 3); control (n = 3)	- 1 month baseline; 2 month follow up. - Selection and plate waste recorded by observation.	- Fruit selection (FS) and consumption (FC), Vegetable selection (VS) and consumption (VC), and milk selection (MS) and consumption (MC).	FS: +++ FC: +++ VS: +++ VC: +++ MS: +++ MC: [=]
Hakim & Meissen (2013); Midwest, US [29]	Cohort	Plate waste was recorded for 2148 meals by direct observation (n = 2, 064) or objective weighing (n = 84).	- 1 month baseline; 1 month intervention. - Selection and plate waste recorded by observation or direct weighed measure.	- Consumption of fruit (CF) and vegetable (CV).	CF: ++ CV: ++
Hanks et al. (2016); New York, US [30]	Cohort Analytic	10 elementary schools - 1 control condition (C: n = 2), 3 treatment conditions (T1: n = 2; T2: n = 3; T3: n = 3, respectively). 22206 observations recorded.	- 2 weeks baseline; 4 week intervention. - Food preparation records. - Tallys of number of students taking a salad serving (visual observation).	- Vegetable and salad selection (VS).	Food preparation records - T1 VS: [=] - T2 VS: [=] - T3 VS: + Tallys of selection - T1 VS: + - T2 VS: [=] - T3 VS: +++
Keller (2017); Atlanta, US [31]	Cohort	1 school, 6th grade students.	- 3 day baseline; 3 day intervention (1 day treatment 1 [T1, branding], 1 day treatment 2 [T2, advertising], 1 day treatment 3 [T3, variety]). - Data recorded by observation.	- Fruit selection (FS) and consumption (FC).	T1 - FS: [=] - FC: +++ (reduction) T2 - FS: ++ - FC : ++

					(reduction) T3 - FS : +++ - FC : [=]
Miller et al. (2015); US [32]	Cohort	1 elementary school, Kindergarten – 5th grade classes, n = 758.	- 1 day baseline; 2 day increased portion size intervention. - Pre-consumption weight estimates were compared to actual post-consumption weight.	- Carrot consumption (CC), apple sauce consumption (AC), and orange consumption (OC).	CC: [=] AC: +++ OC: +++
Redden et al. (2015); Minnesota, US [33]	Cohort	1 elementary school; Kindergarten – 5th Grade. Study 1: n = 755. Study 2: n = 558.	Study 1: - 1 day control; 1 day intervention. - Study days conducted 3 months apart. - Visual estimation and average portion sized weights used to approximate consumption. Study 2: - 2 day control; 3 day intervention. - Study conducted over 3 months. - Visual estimation and average portion sized weights used to approximate consumption.	- Study 1 - Carrot consumption (CC). - Study 2 – Broccoli consumption (BC).	Study 1 – CC: +++ Study 2 – BC: +++
Reicks et al. (2012); Minnesota, US [34]	Cohort	1 elementary school; n = 800	- 1 day control; 1 day intervention. - Consumption calculated from plate waste.	- Green bean consumption (GBC), and carrot consumption (CC).	GBC: = CC: I < C +++
Samek (2016); Chicago, US [35]	Cohort Analytic	8 schools (C n = 27 classrooms; Gift n = 30 classrooms; Goal n = 33 classrooms); n = 1,483.	- 1 day intervention; 1 day baseline. - Milk sales records.	- Choice of white milk control (WCc), choice of white milk Gift condition (WC1), choice of white milk Goal condition (WC2).	WC1 > WCc: ++ WC2 > WCc: +
Schwartz (2007); New England, US [36]	Cohort Analytic	2 elementary schools; I and C; n = 646.	- 2 day baseline; 2 day intervention. - Direct observation of fruit/fruit juice selection and consumption.	- Fruit/Fruit juice selection (FS/FJS) and consumption (FC/FJC).	Day 1 - IFS 4x more likely than CFS. - FJS: [=] No significance level reported.
Swanson (2009); Kentucky, US [37]	Cohort	1 school, Kindergarten – 4th grade students; n = 491	- 1 day intervention; 1 day follow-up control. - Observation via the digital photography method.	- Orange selection (OS) and consumption (OC), apple selection (AS) and consumption (AC).	OS and OC increased. AS: [=] AC: [=]
Wansink et al. (2013); New York, US [38]	Cohort Analytic	6 middle schools; Control = 3, Intervention = 3.	- 1 month intervention. - Recorded tray waste and calculated apple sales records.	- Apple selection (AS) and apple consumption (AC).	AS: +++ AC: [=]

Wansink et al. (2012); New York, US [39]	Cohort	7 schools; n = 209.	- 1 day baseline control; 1 day post-test control; 3 day intervention, 3 treatment groups; Elmo branded apple (T1), Elmo branded cookie (T2), unknown branded apple (T3). - Unspecified data collection methods.	- Apple selection (AS) and cookie selection (CC).	T1 AS: [=] T2 CS: [=] T3 AS : [=]
Wansink et al. (2012); New York, US [40]	- St1: Cohort - St2: Cohort Analytic	- Study 1: n = 147 - Study 2: Purchase observations for 1552 students.	- Study 1: 3 day data collection. - Selection and plate waste was recorded. - Study 2: - 20 day baseline data collection; 20 day intervention. - Hot vegetable selection was recorded.	- Study 1 – Carrot consumption control (CCc), carrot consumption labelled (CC1), carrot consumption attractive label (CC2) - Study 2 – Hot vegetable selection (HVS).	Study 1 - - CC2 > CC1: + - CC2 > CCc: + Study 2 – - HVS: +++
Zellner et al. (2016); US [41]	Cohort	1 school, grades 3 and 4; n = 25.	- 1 day control, fruit served at the same time as vegetable; 1 day intervention, fruit served as a dessert, after vegetable. - Consumption data recorded by trained observers.	- Consumption of kale (KC)	KC: ++
Zhuzhina (2016); California, US [42]	Cohort	2 schools, grades 1 to 5.	- 2 or 3 days baseline data collection per school; 5 days intervention data collection per school. - Data recorded using the digital photography method.	- Fruit selection (FS) and consumption of whole portion (FC), and vegetable selection (VS) and consumption of whole portion (VC).	School 1 (B.S): FS increased; VS increased; FC increased; VC increased. School 2 (W.P): FS decreased; VS decreased; FC increased; VC increased.

Note: For those studies that reported varying sized participant samples for different data collection days, the largest sample is reported.

Key

- + = p = .05
- ++ = p = .01
- +++ = p = .001
- [=] = no change

Table 3. A synopsis of the studies measuring global nutritional improvement.

Study/Country	Study Design	Sample Characteristics	Duration/ Measurements	Outcomes	Main Results
Ensaff et al. (2015); Yorkshire, UK [43]	Unclear	2 Secondary schools; n = 980; 218,796 cafeteria transactions recorded	- Baseline and post-intervention data extracted from cafeteria records from the academic year; 6 week intervention. - Cashless electronic system automatically recorded purchase information.	- Selection of designated healthy food items - vegetarian daily specials (VDS), sandwiches containing salad (SS), fruit pots and whole fruit (F).	VDS: +++ SS: +++ F: +++
Graham (2015); Texas, US [44]	Cohort	1 elementary school, Kindergarten – 5th grade classes, n = 25 classrooms. 4 Treatment groups (T1; T2; T3; T4).	- 43 day baseline; 23 day intervention. - Self reported food journals, monitored by direct observation of a selection of meals.	- Selection of nutritionally coded entrees according to a traffic coding system (e.g. red = unhealthy)	Minimal differences associated with nutritional labelling. "Green" entrée choices more likely with increased variety.
Hanks et al. (2013a); New York, US [45]	Cohort Analytic	2 Elementary schools; n = 272	- 2 weeks baseline. - 2 or 3 weeks intervention. - Sales records were recorded.	- Selection of healthy entrée (HES) or unhealthy entrée (UES).	More likely to select a healthy entrée if pre-ordered.
Hanks et al. (2013b); New York, US [46]	Cohort Analytic	2 Junior-Senior High Schools; 3762 observations.	- 2 month baseline; 2 month intervention. - Recorded tray waste.	- Selection and consumption of fruit (FS/FC) and vegetables (VS/VC).	FS: + VS: +++ FC: ++ VC: +++
Hanks et al. (2012); New York, US [47]	Cohort	1 High school; Control = 602 observations, Intervention = 482 observations.	- 8 week baseline period; 8 week intervention. - Recorded tray waste.	- Selection of designated healthy food items (HFS). - Consumption of designated healthy food items increasing (HFC). - Consumption of unhealthy food items decreasing (UFC).	HFS: ++ HFC: [=] UFC: ++
Miller et al. (2016); Florida, US [48]	Cohort Analytic	Students in 5th and 6th grade.	- 2 week baseline; 2 week intervention. - Control (C)– no treatment. Treatment 1 (T1) orders recorded via a web-based programme with no prompt, Treatment 2 (T2) or with prompt.	- Selection of healthy meal components: meat/alternative (MAS), grain (GS), fruit (FS), vegetable (VS), and dairy (DS).	T1 > C for FS, VS & DS. T2 > T1 for FS, VS & DS.
Siegel et al. (2015); Cincinnati, US [49]	Cohort	1 elementary school; n = 297	- 2 month baseline; 2 month intervention. - Sales records from till receipts.	- Selection of white milk (MS), chocolate milk (CS), healthy entrée (HS), fruit (FS) and vegetables (VS)	MS: +++ CS: +++ (decrease) HS: [=] FS: [=] VS: > 8 data points above mean (sig.).
Wansink et al. (2013); New York, US [50]	Cohort Analytic	1 School district; Control = 1460, Treatment = 35.	- 5 week intervention. - Point of sale purchase information.	- Selection of fruits (FS), vegetables (VS), starch (SS), milks (MS), snacks (SnS) and a-la-carte items (ALCS).	FS/VS/SS/MS/ALCS: [=] SnS*: [=] *Cookie Selection: -

Note: For those studies that reported varying sized participant samples for different data collection days, the largest sample is reported.

Key

- + = p = .05
- ++ = p = .01
- +++ = p = .001
- [=] = no change